NA 8-555

IN-40190

P-3

TWO COMPONENT MODEL FOR X-RAY EMISSION OF RADIO SELECTED QSO'S

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ABSTRACT: Using a large database of radio, optical, and X-ray luminosities of AGNs with survival analysis, we find the X-ray emission of the radio selected QSOs has two components. One is related to the optical luminosity and the other is related to the radio luminosity.

Although the main emission mechanism of radio selected QSOs is thought to be synchrotron emission or a synchrotron self-Compton mechanism, we see a relation between the radio luminosity and the X-ray luminosity that is weaker ($\ell_x \propto \ell_r^{0.5}$) than that of BL Lac objects ($\ell_x \propto \ell_r^{0.8}$), which are definitely non-thermal sources. Owen, Helfand, & Spangler (1981) found that the radio luminosity of 10 GHz selected radio QSOs is strongly correlated with the X-ray luminosity. Owen & Puschell (1982), however, found that the radio luminosity of X-ray strong radio selected QSOs is not strongly correlated with the X-ray luminosity. Zamorani (1984) proposed an explanation for these results. He suggested that the radio selected QSOs have two different X-ray emission mechanisms such that

$$\ell_x = a\ell_{opt}^{\alpha} + b\ell_{radio}^{\beta}$$

To check this model, we conducted a statistical study with survival analysis which treats upper limit problems correctly and removes the selection effect due to flux limited observations in luminosity - luminosity relations (Feigelson & Nelson 1985; Isobe, Feigelson, & Nelson 1986). We also paid particular attention to the radio luminosity. Since many radio selected QSOs have extended lobes and jets which do not represent present status of the radio activity of the QSOs, we carefully selected out the radio cores (Kembhavi, Feigelson & Singh 1986). With 156 radio selected QSOs (61 upper limits), we can get much better statistical results compared to previous work.

The simplest way to check the model is to make fits to the observed data. We fit three models (Fig. 1):

1) $\log(\ell_x) = 29.0 + 0.48 \log(\ell_r)$ (solid line),

(NASA-CR-179923) TWO COMPONENT MODEL FOR X-RAY EMISSION OF RADIO SELECTED QSO'S (Pennsylvania State Univ.) 3 p CSCL 03B

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2) $\log(\ell_x) = 19.0 + 0.77 \log(\ell_r)$ [$\log(\ell_r) > 33.8$],

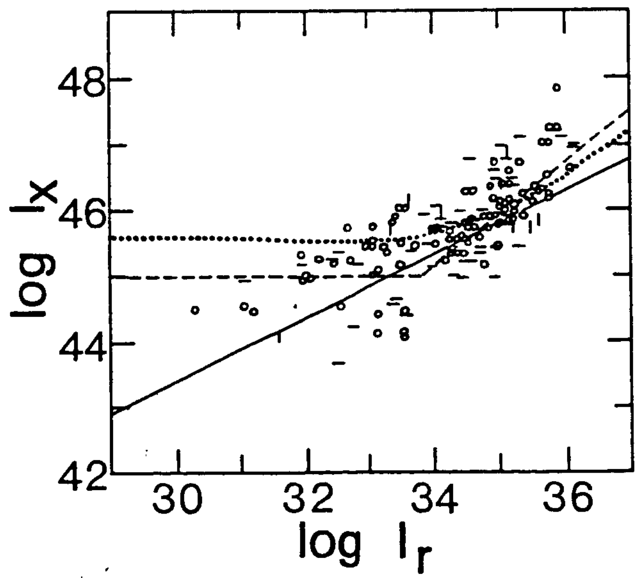
$\log(\ell_x) = 45.0$ [$\log(\ell_r) \leq 33.8$] (broken line),

3) $\ell_x = a\, \ell_o^{0.63} + b\, \ell_r^{0.75} + c$ (dotted line).

The value $\alpha$ and $\beta$ are directly adopted from Zamorani's paper. Using generalized Kendall's $\tau$ method (Isobe et al. 1986), we fit these lines to the data. Since there is no reliable goodness-of-fit test for censored (or upper limit) data sets, we compared dispersions of data around these models. This computation can be done using the Kaplan-Meier estimator. The dispersions are 0.65, 0.63, and 0.44, respectively for the three models. Zamorani's model is actually very good in reducing the dispersion of the data.

To reinforce the result, we also checked partial rank correlations. For censored data sets, only relative measures of correlation rather than absolute probabilities are obtainable. In Table 1, we show the partial rank correlation coefficients for radio selected QSOs, optically selected QSOs, X-ray selected AGN, and radio selected BL Lac

Figure 1: The plot of the 0.5-4.5 keV X-ray luminosity against the 5 GHz radio core luminosity density of the radio selected QSOs. The circles represent detected points and the bars represent upper limits. The dotted line is the straight line model fit, the broken line is the two straight line model fit, and the solid line is Zamorani's model.



objects. As can be seen, the main X-ray emission mechanism of optically selected QSOs and X-ray selected AGNs is related to their optical luminosity. The radio selected BL Lac objects have the strongest correlation between $\log(\ell_r)$ and $\log(\ell_x)$ and this suggests that the X-ray emission is due to the non-thermal emission. The radio selected QSOs show the highest correlation between $\log(\ell_o)$ and $\log(\ell_x)$, though the relation between $\log(\ell_r)$ and $\log(\ell_x)$ is also strong. This again suggests the two component model.

From these analyses, we conclude that X-ray emission in the radio selected QSOs is likely to have two components; one is related to the optical luminosity and the other is related to the radio luminosity. The X-ray emission related to the optical luminosity may be thermal, similar to the optically selected QSOs, and has a flatter spectral index (slope $\sim$ 0.5) in Fig. 1. The X-ray emission related to the radio luminosity may be non-thermal, similar to the BL Lac objects, and appears to have a steeper spectrum (slope $\sim$ 0.8).

This work was supported by NASA grant NAG 8-555 and by NSF Award AST 83-51447.

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Table 1: Partial rank correlations. The first line shows the relation examined and the second line shows the fixed quantity. The results are relative and cannot be compared between different samples.

| Sample | Correlation | $\ell_r-\ell_x$ | $\ell_o-\ell_x$ | $\ell_o-\ell_r$ |
|---|---|---|---|---|
| | Fixed Quantity | $\ell_o$ | $\ell_r$ | $\ell_x$ |
| Radio Selected QSOs | | 0.31 | 0.45 | 0.13 |
| Optically Selected QSOs | | 0.05 | 0.16 | 0.08 |
| X-ray Selected AGNs | | 0.07 | 0.64 | 0.07 |
| Radio Selected BL Lacs | | 0.56 | 0.45 | 0.34 |